THE HYDROGEOLOGY OF AN AREA NEAR MARIENTHAL, WICHITA COUNTY, KANSAS

by

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INTRODUCTION

Purpose of Investigation

Increased use of ground water for irrigation since 1950 has resulted in serious depletion of ground-water reserves in west-central Kansas. The severity of the problem has been discussed by many authors, notably Slagle and Weakly (1976) and Gutentag and Stullken (1976). The objectives of this investigation are to describe in detail the hydrogeologic system of an irrigated area in Wichita County, and to relate the geology to past and future availability of ground water for irrigation.

The U. S. Geological Survey is cooperating with the Western Kansas Groundwater Management District No. 1 in an intensive study in this area to see if ground-water resources can be conserved by improving irrigation efficiency. This report should supplement the study by detailing the geology of the aquifer and its hydrogeologic properties.

Location of Area

The project is located in a 12-square mile area in northeastern Wichita County two and one-half miles north of Marienthal, and south of the Ladder Creek valley (Fig. 1). All land in the area is in agricultural production, and the area is undissected by any major drainage systems.

Previous Investigations

The hydrology of Kansas, including the project area, was first discussed by Haworth (1897). Darton (1905) briefly described the geology and ground water resources of Wichita County and the geology of the Ogallala Formation in the central Great Plains. Elias (1931) described in detail the geology of the Pleistocene loess, the Ogallala Formation and Upper Cretaceous

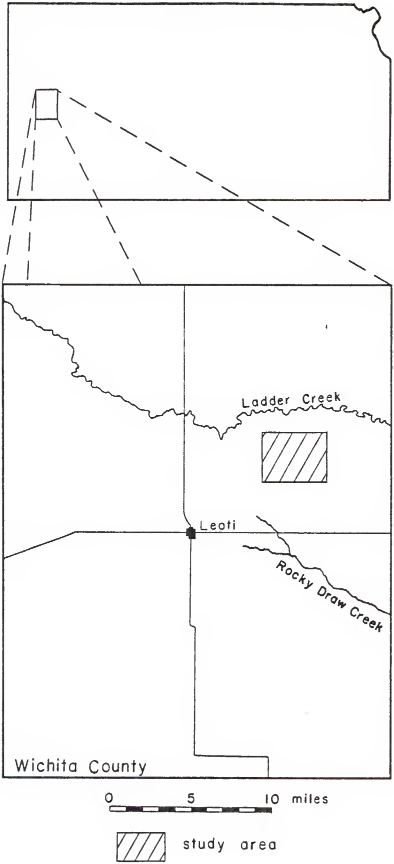

Figure 1. Location of project in Wichita county, Kansas.

formations of Wallace County, north and west of the study area. The geology and ground-water resources of Wichita and Greeley counties were discussed by Prescott, et al. (1954). Frye, et al. (1956) studied the stratigraphy and paleontology of the Ogallala Formation in northwestern Kansas. Bradley and Johnson (1957) described the geology and hydrology of the area surrounding Ladder Creek, including the project area. Gutentag (1963) differentiated the Pliocene and Pleistocene in southwestern Kansas based on lithology and fossil assemblage. Hamilton (1965) mapped and described the soils of Wichita County.

Recent investigations of the ground-water resources of Wichita County and west-central Kansas are reported in several publications. Pabst and Jenkins (1974) noted changes in water levels in west-central Kansas and Stullken, et al. (1974) published other hydrogeologic data from the same area. The results of chemical quality studies for west-central Kansas were published by Hathaway, et al. (1975, 1977). Slagle and Weakly (1976) described the ground-water resources of Greeley and Wichita counties and the outlook for future irrigation development.

Well Numbering System

The wells and test holes in this report are numbered according to the Bureau of Land Management system of land subdivision, in the following order: township, range, section, and location within the section. The first numeral indicates the township, the second indicates the range and direction east or west of the Sixth Principal Meridian, and the third indicates the section (Fig. 2). Letters following the section number indicate the quarter section, the second indicating the quarter-quarter section, and the third letter indicating the quarter-quarter-quarter section (10

acre tract). The letters are assigned in a counter-clockwise direction beginning with 'a' in the northeast quadrant. Where more than one well is located within a 10 acre tract, consecutive numbers, beginning with one, are added to the letters. For example, 17-35W-30dcb indicates a well located in the NW¼, SW¼, SE¼, sec. 30, T. 17 S., R. 35 W.

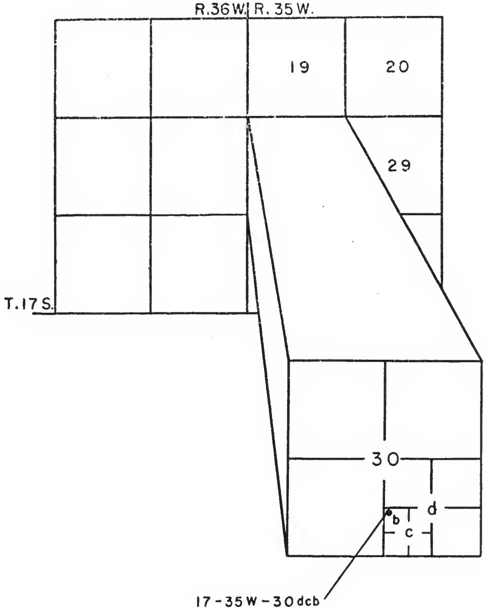

Figure 2. Map of project area illustrating well numbering and location system.

GEOLOGY IN RELATION TO GROUND WATER

Unconsolidated sediments of Quaternary age cover the area. Underlying these deposits are consolidated and unconsolidated sediments of Tertiary age which are the source of water for the area and the principal subject of this report. The Tertiary deposits are underlain by shale and clay of Cretaceous age. The character and ground-water supply of the geologic formations are briefly summarized in Figure 3.

Cretaceous System - Niobrara Chalk Formation

Bedrock in the area is the Upper Cretaceous Smoky Hill Chalk Member of the Niobrara Chalk formation. The Smoky Hill Chalk consists of chalky shale, light to dark gray in color, weathered in the upper part to yellow or yellow-orange. The shale forms an impermeable floor for the aquifer, preventing downward movement of water (Prescott et al., 1954, p. 64-65).

The configuration of the top of the Smoky Hill Chalk is shown by the bedrock contour map (Fig. 4). The erosional surface slopes to the east at an average gradient of 20 feet per mile. A broad valley, trending east-southeast, exists in the east-central part of the project area.

Fractures and solution openings in the Niobrara Chalk yield substantial quantities of water to wells in some areas of western Kansas. In neighboring Scott County, for example, irrigation wells drilled to the upper part of the Smoky Hill Chalk yield from 500 to 1000 gallons per minute (Gutentag and Stullken, 1976, p. 11). There are no wells in the immediate vicinity of the project area known to be producing water from the Niobrara and no evidence to suggest ground-water supples exist in the formation in the area.

System	Series	Group	Formation	Member	Thickness	Character	Water Supply
Quaternary	Pleistocene		Undifferentiated		30-40 ft	Silt and fine sand, mostly eolian.	Lies above water-table.
Tertiary	Pliocene		Ogallala		150-180 ft	Sand, gravel, silt, and clay commonly unconsolidated but locally cemented by calcium carbonate and silica cement into mortar beds.	Yields moderate amounts of water to wells. Water generally of good quality
Cretaceous	Upper Cretaceous	Colorado	Niobrara Chalk	Smoky Hill Chalk	100-500 ± feet	Light to dark gray beds of chalky shale that weather to yellow and yellow-orange clay.	Yields no water to wells in this area.

Figure 3. Age classification, description, and water supply of geologic units.

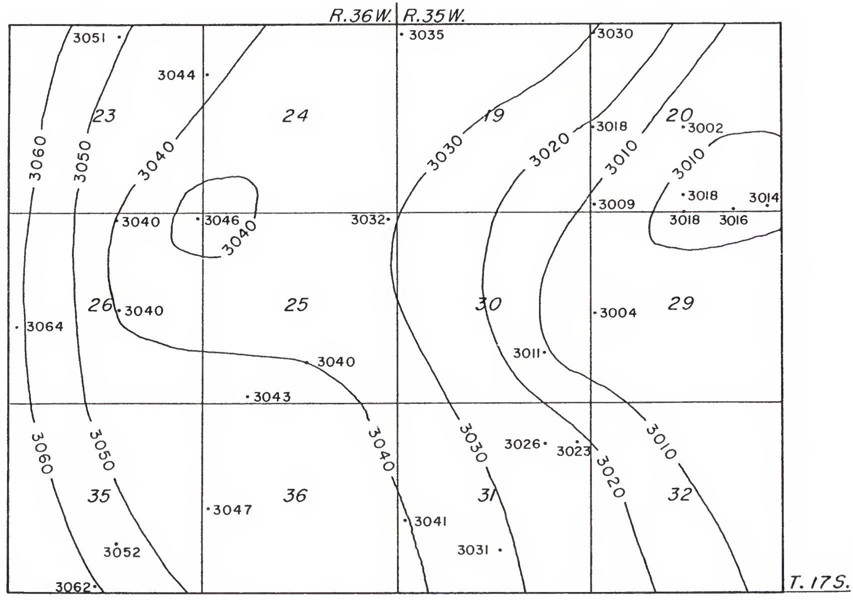

Figure 4. Bedrock contour map showing elevations at the top of the Niobrara Chalk formation.

Tertiary System - Ogallala Formation

The Ogallala Formation of the Pliocene Series, is the principal aquifer of western Kansas and the source of water for all wells in the project area. The Ogallala is of alluvial origin and consists of interbedded silt, sand, gravel, and clay. The beds mostly are unconsolidated but may be cemented by calcium carbonate or siliceous cement (Prescott et al., 1954, p. 65). Calcium carbonate also may occur as thin beds of caliche or limestone. Individual beds of clay and gravel are lenticular and cannot be traced laterally for any appreciable distance. Sand and gravel beds in the lower part of the formation, although poorly sorted, contain the greatest quantities of water (Prescott et al., 1954, p. 67).

The upper part of the formation is characterized by the presence of 'mortar beds', composed of tightly cemented silt and sand. The mortar beds crop out in the Ladder Creek valley north of the study area as massive, resistant ledges resembling old mortar. Although the processes resulting in the formation of the mortar beds are not well known, it is likely that the calcium carbonate cement was deposited by leaching and reprecipitation during the latest phases of Ogallala deposition (Swineford et al., 1958, p. 114). The mortar beds are fractured and discontinuous and probably do not impede downward percolation of subsurface water.

Quaternary System - Pleistocene Series

Unconsolidated clay, silt, and sand of the Pleistocene Series overlie the Ogallala Formation. Loess deposits of silt and clay grade downward to fine to coarse sand reworked from the Ogallala. The Pleistocene sediments are above the water table and are therefore unsaturated. The loess is highly permeable (Prill, 1977) and should allow the infiltration of excess precipitation and irrigation water.

METHODS OF INVESTIGATION

Field Procedure

Maps and Cross Sections.--A base map was constructed from the Pence 15 minute quadrangle and the Russell Springs 3 SE 7.5 minute quadrangle. Elevations of wells and test holes were determined to the nearest five feet from the base map. Water level measurements provided by the U. S. Geological Survey were used to construct a water-table contour map. A bedrock contour map was constructed from logs of test holes drilled and driller's logs provided by the Survey. The water-table contour map and the bedrock contour map were used to determine saturated thicknesses for the development of a saturated thickness map of the aquifer.

Well Logs.--Sample logs, electric logs, and radioactivity logs were obtained from the U. S. Geological Survey for the seven test holes in the area, and from these composite logs were prepared detailing the geology at each drill site. Examination of samples collected during drilling facilitated the preparation of the composite logs. The composite logs were used to make geologic cross sections of the study area.

Collection of Samples.--Samples of the drill cuttings were collected by U. S. Geological Survey personnel during the drilling of each test hole. Each sample represented a mixture of the material encountered in 15 feet of bit penetration. The samples were put into sample bags and labeled with the hole location number and depth interval.

Aquifer Tests.--The formation constants of the quifer were determined at two locations by aquifer tests conducted by the author and other U. S. Geological Survey personnel. In SW¼, SE¼, NW¼, sec. 23, T. 17 S., R. 36 W.,

two irrigation wells are located 101.5 feet apart. One well was turned on and pumped at a constant rate of discharge while the drawdown in the other well was measured with an electric water level indicator attached to a steel tape. Depth-to-water measurements were made to the nearest 0.01 foot at regular intervals for a period of 25 hours.

In the second test, the rate of water-level recovery was determined in two U. S. Geological Survey observation wells located 100 and 200 feet respectively from an irrigation well in SW¼, NW¼, SW¼, sec. 29, T. 17 S., R. 35 W. After pumping at a constant rate of discharge for a period of two days, the irrigation well was turned off and the rate of water-level recovery was measured in each of the observation wells using the same methods as the previous test. Water-level measurements were made for a period of five hours.

Laboratory Procedure

Grain-Size Analyses.--Samples of drill cuttings were analyzed to determine the grain-size distribution of the sediments. Each thoroughly mixed sample was disaggregated and split mechanically until a weight of 70 to 100 grams was obtained. The split samples were separated into size classes using U. S. Standard screens of one-phi interval. After sieving for 15 minutes on a Tyler Ro-Tap, each size fraction was weighed to the nearest 0.1 gram. The size fractions were examined using a hand lens or binocular microscope and the percent aggregate, cemented sand, and limestone fragments were estimated. Cumulative weight percentages were then computed for the unconsolidated fraction of the entire sample.

DISCUSSION AND INTERPRETATION OF DATA

Ground Water

In the Wichita - Greeley county area, the ground water is mostly unconfined, and water-table conditions exist (Prescott et al., 1954, p. 36). Confined or semi-confined conditions may exist locally, however, due to the heterogeneity of the Ogallala aquifer (Slagle and Weakly, 1976, p. 11). Subsurface water in the area is derived primarily from the deep percolation of precipitation, subsurface inflow from areas to the west and north, and recharge from intermittent streams (Prescott et al., 1954, p. 38).

Configuration and Slope of Water Table.--The water table is not a stationary surface but fluctuates in response to recharge and discharge of the ground-water reservoir and changes in atmospheric pressure. The water-table contour map (Fig. 5) is based on water-level measurements made in irrigation wells during January and February of 1977. Winter measurements give a more accurate indication of the shape of the water table, because the aquifer has had time to stabilize following the irrigation season.

Flow lines drawn at right angles to the water-table contour lines show ground water is flowing in an easterly direction (Fig. 5). In the northern tier of sections, the flow lines indicate that water is flowing into the area from the direction of Ladder Creek. Water-level measurements made in the Ladder Creek valley reveal a water-table mound below the creek bed, so the creek may be a source of recharge to the project area. The orientation of flow lines in the southern tier of sections indicate an inflow of ground water from the south, possibly the result of recharge to the aquifer at Rocky Draw Creek south of Marienthal (Fig. 1).

The slope of the water table in general is inversely related to the

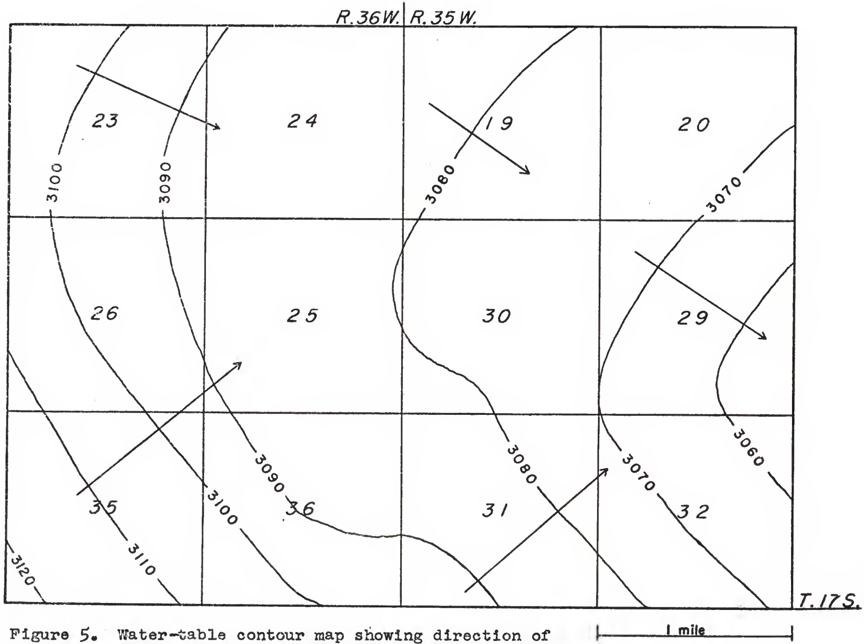

Figure 5. Water-table contour map showing direction of ground water flow. Contour interval 10 feet.

permeability of the aquifer material (Prescott et al., 1954, p. 38). When the slope of the water table is steep, the aquifer is relatively impermeable, but where the aquifer is more permeable, the contours are farther apart. The greatest permeability in the study area could therefore be expected in the north-central part.

The change in the water table from 1948 to 1977 is shown in Figure 6. Water-table elevations in 1948 were taken from a map developed by J. R. Branch (Prescott etal., 1954) at a time when only two irrigation wells were in operation in the project area and the water table was relatively stable. The greatest decline in water levels has occurred in the central and east-central parts of the study area. Declining water levels have resulted in the saturated thickness of sediments being reduced to less than 50 feet in some parts of the project area (Fig. 7). The greatest saturated thickness is in the eastern part of the study area where the depth-to-bedrock is greatest.

The extent of the depletion of ground-water researves is best illustrated by the map showing percent decline in saturated thickness (Fig. 8). The loss of saturated thickness has been 50 percent or more in most of the area with only the northeast corner showing less than 40 percent decline.

Well Logs

Interpretation.--Well logs are important tools in the determination of subsurface geology. Several kinds of logs can be utilized to determine the lithology of water-bearing rock including sample logs, electric logs, and radioactivity logs. These three logging methods were used by the U. S. Geological Survey to describe the geology in all of the test holes drilled in the project area.

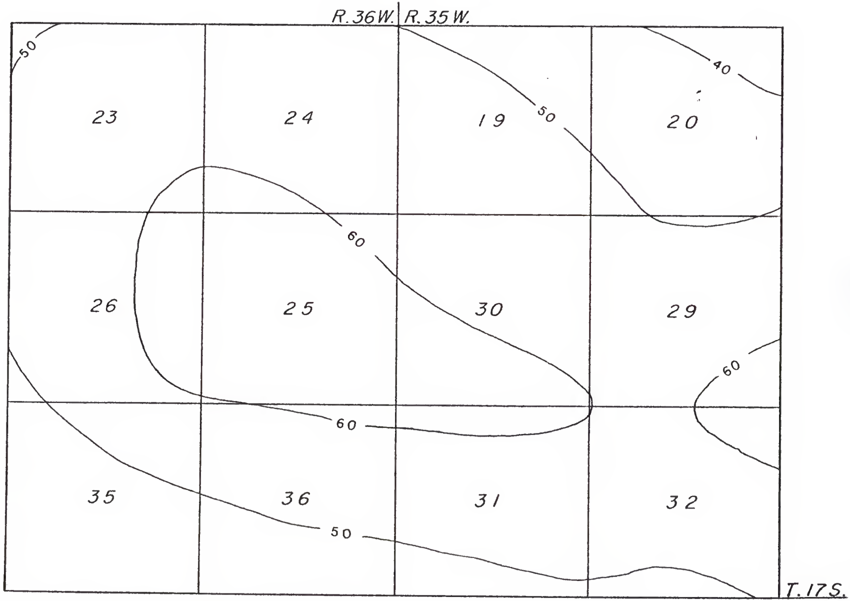

Figure 6. Water level decline, 1948 to 1977, in feet. Contour interval 10 feet.

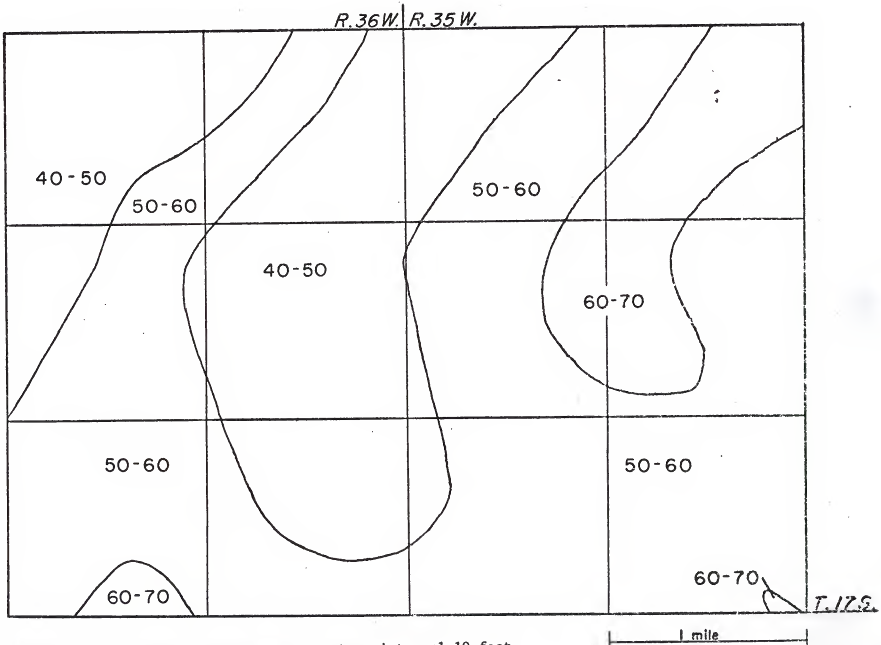

Figure 7. Saturated thickness map. Contour interval 10 feet.

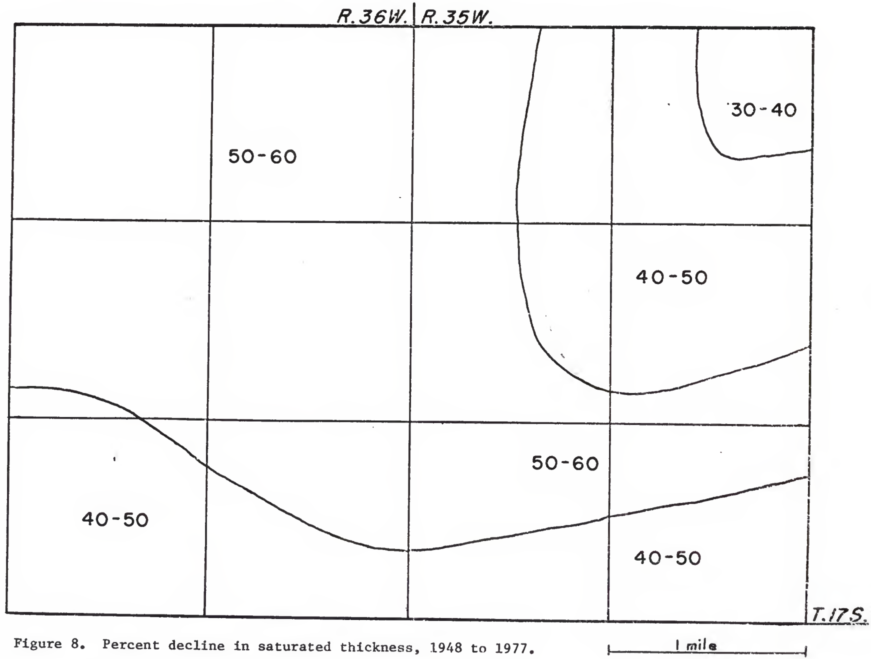

Figure 8. Percent decline in saturated thickness, 1948 to 1977.

Sample logs were kept during drilling which described the cuttings brought to the surface by the drilling mud. The nature of the material, including grain size and color of silt and clay, was recorded together with the approximate depth from which the material was derived. The lag between the time the sediments were drilled and the time they reached the surface was estimated and the recorded depth adjusted accordingly. Variable drilling rates and differential settling of different sized particles made estimation of sample depths difficult. Sample logs were most useful when used in conjunction with geophysical logs which indicate sample depth more accurately.

Geophysical logs were made with portable logging instruments in all test holes immediately after drilling. Although geophysical logs do not directly measure the porosity or permeability of a formation, they do measure other aquifer properties which determine the water-yielding characteristics of the aquifer (Johnson Div., 1975, p. 166). Comparison of the geophysical logs of one test hole in the project (Fig. 9) shows the differences in the logs and how they can be related to the porosity and permeability of the aquifer. The descriptive log in Figure 9 is an illustration of the composite log for test hole 17-36W-35cdd given in Appendix I.

The gamma-ray log measures the natural radiation of certain radioactive elements which may be present in some strata within the formation. Clay and shale commonly contain more radioactive isotopes of uranium, thorium, and potassium than limestone or sand, so greater gamma-ray intensity on gamma-ray logs usually indicate clay or shale beds. The strongest gamma-ray intensity in Figure 9 corresponds to a clay layer immediately below the mortar bed at the top of the Ogallala Formation. The weakest intensities correspond to coarse sand and gravel zones at the base of the Pleistocene

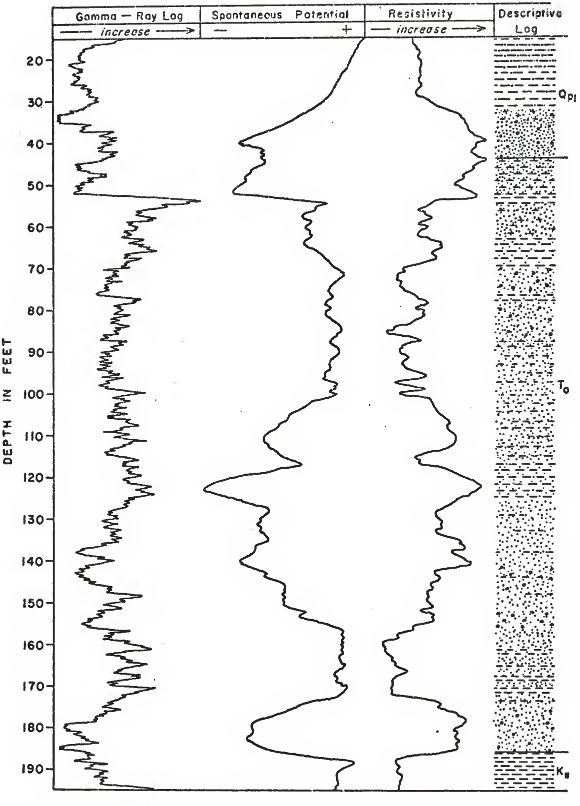

Figure 9. Geophysical and descriptive logs of test hole 17-36W-35cdd.

sediments and the base of the Ogallala. In some test holes strong gamma-ray peaks were produced by thin layers of silica near the top of the Ogallala, but these could be distinguished from clay beds by comparison with sample logs.

Electric logging methods produce two types of logs, spontaneous potential and resistivity logs. The spontaneous potential or SP log indicates the potential difference between the drilling mud and water in the formation because of electro-chemically created currents at the mud-water interface (Johnson Div., 1975, p. 169). The SP log is used to locate the contact between permeable and impermeable beds. The resistivity log indicates the resistance of pore fluid to the flow of an artificially generated current. Generally, fresh-water aquifers and dense rocks will have higher resistance whereas clay layers and sediments containing saline water will have the least resistance (Johnson Div., 1975, p. 171). Contacts between permeable and impermeable beds usually produce sharp breaks on resistivity logs, such as that delineating the contact between the basal sand and gravel of the Ogallala and the shale of the Niobrara (Fig. 9).

Development of Composite Logs.--Information on the lithology of an aquifer is most reliable when based on a comparison of several types of logs (Davis and DeWiest, 1966, p. 313). Composite logs were developed for the stratigraphic test holes in the project from comparison of sample logs with the electric and radioactivity logs. These logs, together with driller's logs provided by the U. S. Geologic Survey from local driller's records, were used in the construction of geologic cross sections (Fig. 10). The location of the test holes, driller's logs, and cross sections are shown in Figure 11.

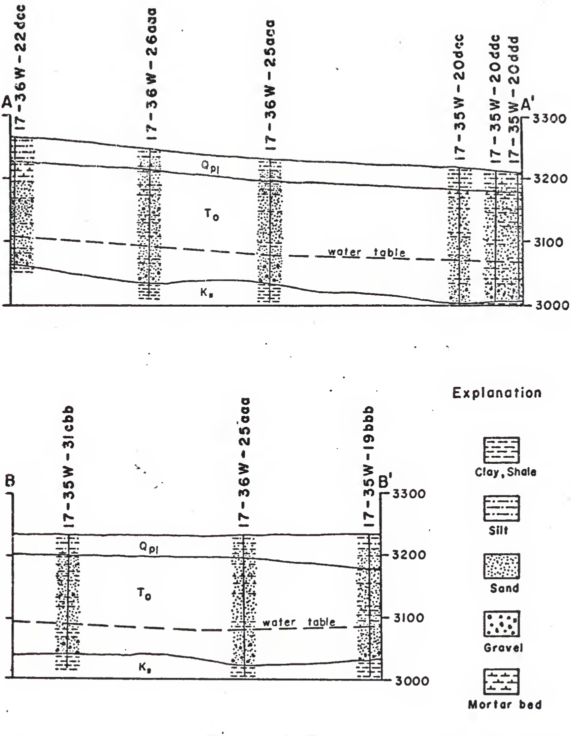

Figure 10. Geologic cross sections and water table profile. (See figure 11 for location.)

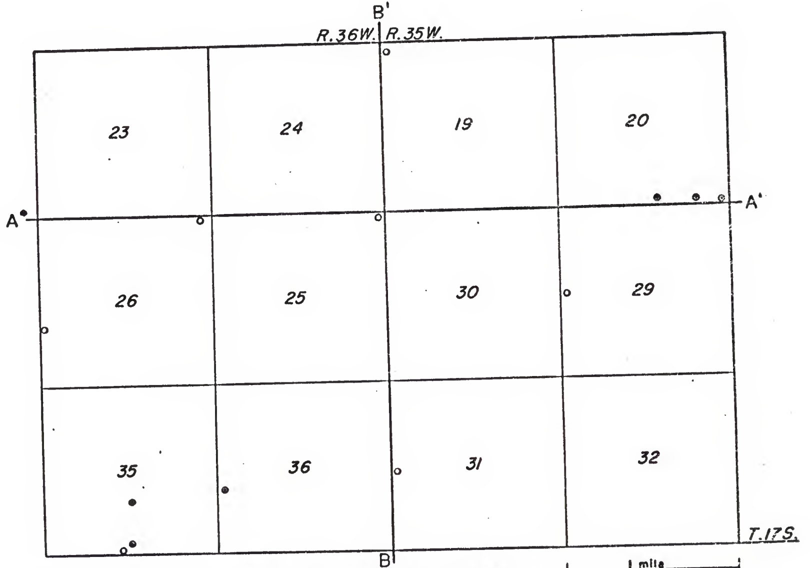

Figure 11. Location of cross sections, and test holes and driller's logs used to construct cross sections.

o test hole   ⊙ driller's log

The cross sections show the discontinuity of clay, sand, and gravel layers in the aquifer. In most test holes there is a sand and gravel layer at the base of the formation, although the thickness of the layer varies greatly. Many of the logs show a layer of silt and clay just above the sand and gravel layer, which suggests that semi-confining conditions could be present locally in the aquifer. The lenticular nature of the layers, however, insures the more permeable layers of the aquifer are hydrologically interconnected.

Aquifer Tests

Principles.--The aquifer properties or formation constants most commonly used to describe the ability of an aquifer to store and transmit water are the coefficients of storage and transmissibility. The storage coefficient (S) is defined as the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in head. In a water table aquifer the storage coefficient is the same as the specific yield (Sy), the quantity of water the material will release when drained by gravity. Values of S for water table aquifers range from 0.01 to 0.35; values for artesian aquifers range from 0.00001 to 0.001.

The coefficient of transmissibility (T) is the rate at which water will flow through a vertical strip of aquifer one foot wide and extending through the full saturated thickness with an hydraulic gradient of 1.00. The transmissibility may range from less than 1,000 to more than 1,000,000 gpd/ft. (Johnson Div., 1975, p. 102-3). The transmissibility may be used to compute the coefficient of permeability (P), defined as the transmissibility divided by the saturated thickness. The coefficient of permeability expresses the volume of water that will flow in a unit time under a unit

hydraulic gradient through a unit area of aquifer, and may also be referred to as the hydraulic conductivity (Gutentag and Stullken, 1976, p. 14).

The aquifer coefficients may be determined by measuring the effect on nearby observation wells of pumping a well at a constant rate. Equations have been developed to express the relation of the transmissibility and storage coefficients to the drawdown in the vicinity of the pumped well. The equations are solved by plotting the drawdown in one or more observation wells versus time or distance from the discharging well.

The first such equation was derived by Theis (1935) from an analogy with conductive heat flow. During an aquifer test, values of drawdown (s) measured at an observation point a known distance (r) from the pumped well are plotted versus time (t) on logarithmic graph paper, and the resulting curve is superposed on a 'type curve' of W(u) versus u, where u is defined by the equation:

$$u = \frac{1.87\ r^2\ S}{T\ t}$$

and W(u) is the well function of u. A match point is located on the two curves and the corresponding s and t values are used to compute S and T from the Theis formula.

The Theis non-equilibrium formula is based on several assumptions including: (1) the aquifer is homogeneous and isotropic, and (2) water is discharged from storage instantaneously with a decline in head. In an unconfined aquifer, water is removed from storage by gravity drainage of the interstices. Boulton (1963, p. 470) noted that in the early stages of pumping, the water-bearing material above the cone of depression does not immediately release water from storage. This delay in yield results in a value of S much smaller than the ultimate specific yield of the aquifer.

Application of the Theis method to water-table aquifers is possible only after sufficient time has elapsed for the effects of delayed gravity drainage to become insignificant.

A method was devised by Boulton (1963) and further developed by Prickett (1965) to determine the formation constants of a water table aquifer from aquifer test analysis, taking into account delayed gravity drainage. A series of type curves (Fig. 12) are used to analyze both early and late time-drawdown data. The data plot of drawdown versus time is first superposed on the 'type A curve' and a match point located. Values of T and S are computed by substituting the coordinates of this match point into the equation:

$$s = \frac{114.6\ Q}{T}\ W(u_{AY},\ r/D)$$

Q is the well discharge, r/D is the type curve number, and u_{AY} is defined by the equation:

$$u_{AY} = \frac{2693\ r^2\ S}{T\ t}\ .$$

Transposing the data plot to the right-hand side of the same curve, a second match point is located, and from the above equations values for T and Sy can be determined. The value of transmissibility obtained should be approximately the same, whereas the values of S and Sy could differ greatly depending on the effects of delayed gravity drainage.

The formation constants of an aquifer may be determined from the recovery of the water level in a well after it has been shut off. Recovery data are most useful as a check on aquifer test analyses by drawdown methods. However, in the absence of drawdown data, recovery data can be used for limited calculations of aquifer capabilities (Johnson Div., 1975, p. 136). The rate of recovery depends on the discharge prior to shutoff and the

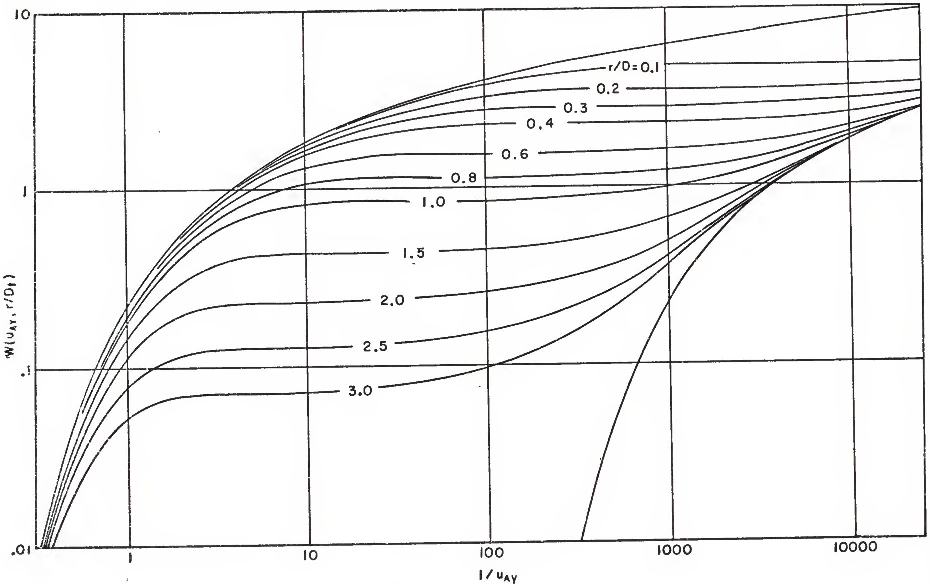

Figure 12. Delayed yield type curves. Adapted from Lohman (1972).

transmissibility. The relationship is expressed by the formula:

$$T = \frac{264\ Q}{s'} \log t/t'$$

where s' is the residual drawdown and t' is time since pumping stopped. This formula can be used to calculate the transmissibility from the semi-logarithmic plot of residual drawdown versus the ratio of time since pumping started to time since pumping stopped.

Evaluation of the Data.--The data from the aquifer test at irrigation well 17-36W-23bcc was analyzed using Boulton's method for unconfined aquifers. The observed drawdowns were adjusted to compensate for the change in transmissibility caused by the decrease in saturated thickness that occurs as the aquifer is dewatered above the cone of depression during pumping (Walton, 1970, p. 224). The drawdowns are adjusted according to the formula:

$$s_a = s_{wt} - \frac{s_{wt}^2}{2m}$$

where s_a is the adjusted drawdown, s_{wt} is the observed drawdown, and m is the original saturated thickness. The data plot and calculations are shown in Figure 13.

Although a good match was obtained between the early time-drawdown data and the type curves, no match could be determined using late time-drawdown data. The test probably was not of long enough duration for the effects of delayed gravity drainage to dissipate. The storage coefficient computed from the early time-drawdown data should not be considered representative of the aquifer without further evidence of confined conditions. Since the computed transmissibility is not a function of time, the value that would be obtained from the late time-drawdown data should be approximately the same.

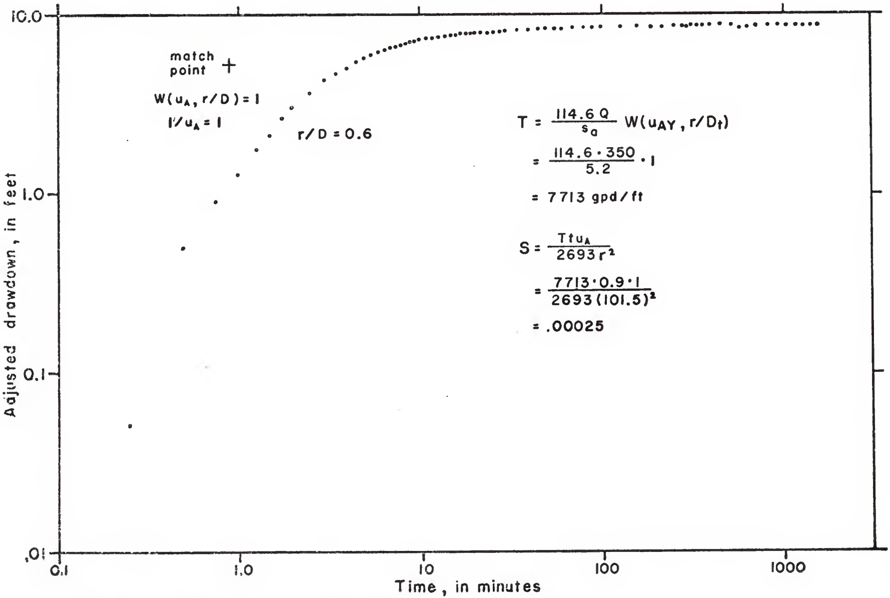

Figure 13. Data plot from the aquifer test at 17-36W-23bcc.

The recovery test on well number 17-35W-29cbc$_1$ was analyzed as shown in Figure 14. The storage coefficient cannot be computed from the residual drawdown curve, and since no drawdown data were available before pumping stopped, no other method of analyzing the data was possible (Johnson Div., 1975, p. 142-3).

The transmissibility values computed from the recovery test, while much larger than that obtained from the previous test, are in agreement with transmissibilities determined by Gutentag and Stullken (1976) and Slagle and Weakly (1976) in recent west-central Kansas studies. Differences in transmissibility within the project area and the corresponding differences in permeability (Table 1) can be explained primarily by differences in lithology of the aquifer between the test sites.

Table 1. Summary of aquifer test results.

Location number of test	Well discharge (gpd)	Length of test (min.)	Coefficient of transmissibility (gpd/ft)	Saturated thickness (ft)	Coefficient of permeability (gpd/ft^2)
17-35W-29cbc (1)	675	300	104,800	61	1,720
(2)	675	300	99,000	61	1,622
17-36W-23bcc$_1$	350	1572	7,700	42	183

Sample Grain-Size Analyses

Individual grain-size weights were used to compute cumulative weight percentages for each sample collected below the 1948 water table elevations (Appendix II). Grain-size distribution curves were plotted on semi-logarithmic paper with the cumulative weight percentages on the arithmetic ordinate and grain size in millimeters on the logarithmic abscissa (Figs. 15, 16, and 17). The size-frequency curves were used to determine statistical parameters describing average grain size and dispersion. Average

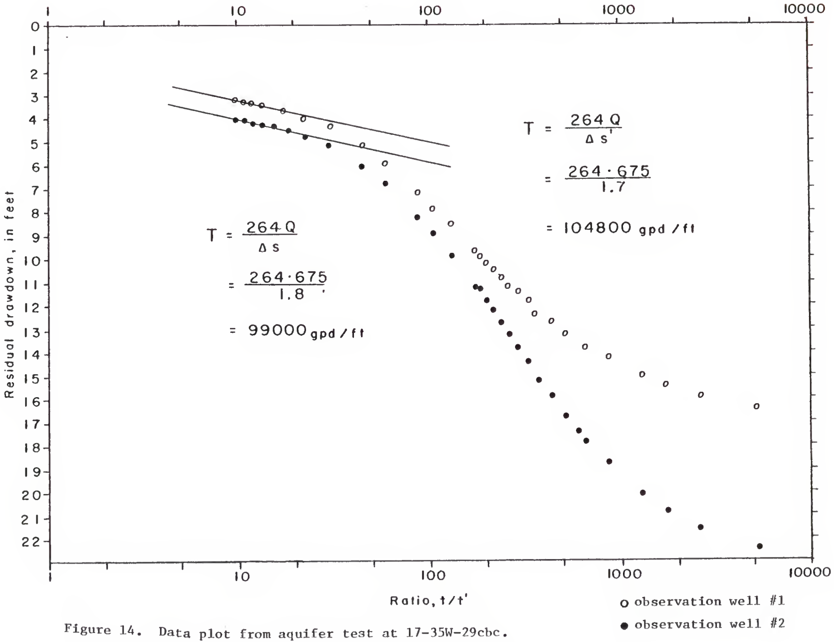

Figure 14. Data plot from aquifer test at 17-35W-29cbc.

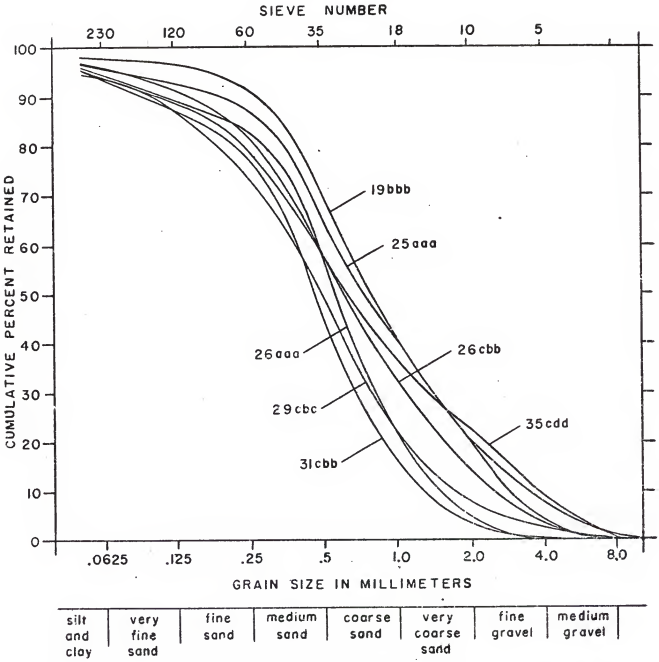

Figure 15. Size-frequency distribution curves for samples from the zone of saturation.

31cbb section number and location

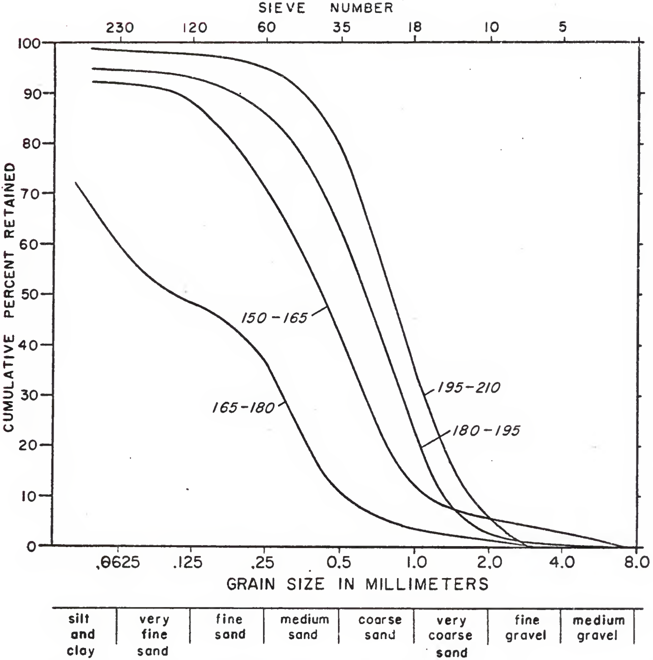

Figure 16. Size-frequency distribution curves for samples from the zone of saturation at test hole 17-35W-29cbc.

150 - 165 depth of sample

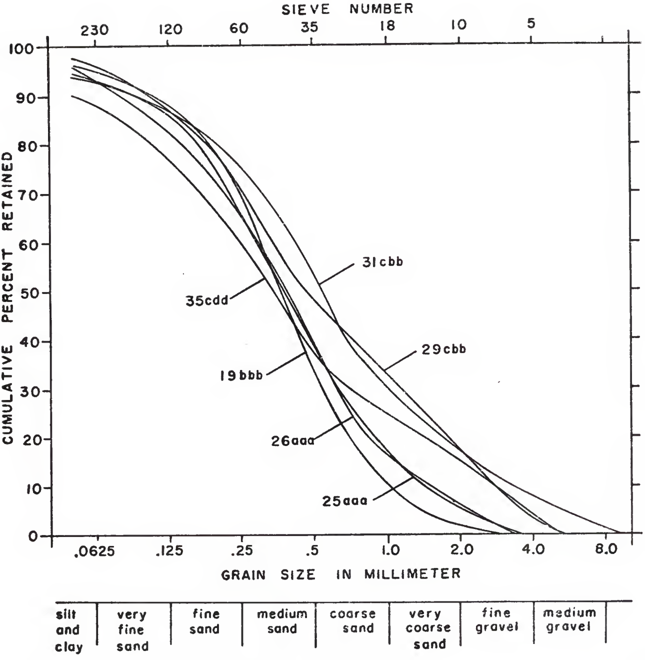

Figure 17. Size-frequency distribution curves for samples from the zone of dewatering.

25aaa section number and location

grain size is expressed by the graphic mean (M_Z), defined by the formula $M_Z = (\varnothing 16 + \varnothing 50 + \varnothing 84)/3$ (Folk, 1974, p. 45). The graphic standard deviation (σ_G) is used to express sorting, and is defined by Folk (1974, p. 45) in the formula $\sigma_G = (\varnothing 16 - \varnothing 16)/2$. All millimeter grain sizes were converted to $\varnothing$ units before beginning computations according to the formula $\varnothing = -\log_2 \xi$ (Krumbein and Monk, 1942, p. 3) where ξ is the particle diameter in millimeters. Subsequently all statistical expressions of grain sizes in this report will use $\varnothing$ units.

Zone of Saturation.--Size-frequency curves representing the zone of saturation (based on 1977 water levels) of each test hole are shown in Figure 15. The symmetrical 'S' shape of the curves is indicative of sediments deposited by flowing water (Walton, 1970, p. 295). Using the Wentworth scale of size classification (Folk, 1974, p. 25) a very wide distribution of grain sizes is indicated from medium gravel to silt and clay with the greatest concentration in the medium to very coarse sand sizes.

Comparison of size-frequency curves for different depth intervals of the saturated sediments from test hole 17-35W-29cbc$_1$ shows a wide variation between intervals (Fig. 16). Three of the curves follow the characteristic 'S' shape, but the fourth curve, representing the drilling depth interval from 165 to 180 feet, shows a steepening in the upper part due to a large silt and clay fraction. The presence of a thick clay layer at this depth is further indicated by the geophysical logs of the test hole (Fig. 18). The thickness and low permeability of the clay layer as suggested by the grain-size analysis and geophysical logs indicate the clay could act as a confining layer for the underlying sand and gravel.

Dewatered Zone.--Size-frequency curves for samples representing the thickness of aquifer dewatered since 1948 are similar to the curves for

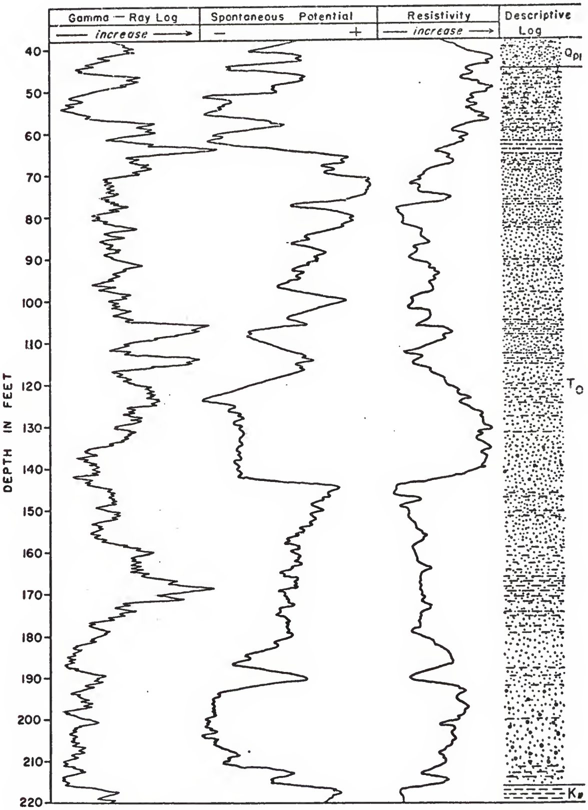

Figure 18. Geophysical and descriptive logs of test hole 17-35W-29cbc.

the zone of saturation, except for less curvature in the upper ends of the curves (Fig. 17). This indicates smaller fine to coarse sand fractions and larger silt and clay fractions in the samples from the dewatered aquifer.

Comparison of the overall grain size and degree of sorting for the dewatered zone is shown in Table 2. The mean grain sizes of samples from the dewatered zone are smaller in four of the seven sample locations, and standard deviations of samples from the dewatered zone are greater in six of the seven localities. These data suggest that the dewatered aquifer consists of finer, poorer sorted material than the presently saturated aquifer and therefore would not store or transmit water as well.

Table 2. Phi statistical parameters for samples from the saturated zone and the dewatered zone.

Sample location	Saturated zone		Dewatered zone	
	M_z	σ_G	M_z	σ_G
17-35W-19bbb	0.18	1.40	1.50	1.16
17-35W-29cbc$_1$	1.14	1.51	0.91	1.92
17-35W-31cbb^1	1.22	1.28	0.81	1.92
17-36W-25aaa	0.31	1.43	1.37	1.46
17-36W-26aaa	0.88	1.18	1.48	1.56
17-36W-26cbb	0.66	1.50	0.51	2.08
17-36W-35cdd	0.54	1.88	1.40	2.23

Estimation of Formation Constants

The permeability of an unconsolidated aquifer depends on the size and arrangement of the particles (Johnson Div., 1975, p. 38). Several statistical parameters are commonly used to describe the grain size of sedimentary rocks quantitatively. They include mode, median, graphic mean, standard deviation, skewness, and kurtosis. Definition and application of these parameters are given by Folk (1974, p. 44-48). In the water-well industry, the terms effective grain size and uniformity coefficient also are used to express the grain size and degree of sorting

respectively of water-yielding sand.

Many studies have been conducted to determine the relationship between the grain size measurements of a sediment and its permeability. Rose and Smith (1957) found the effective grain size correlated best with permeability, whereas Pearl (1970) found the amount of gravel present in the sample was related to the permeability. Bedinger (1961) found the permeability to be related to the square of the median grain size. Krumbein and Monk (1942) and Masch and Denny (1966) determined that a relationship existed between permeability and both average grain size and standard deviation. From these and other similar studies it can be concluded that the grain size parameters to be used depend on the geology of the aquifer and the purpose of the study.

Results of sample grain-size analyses were used to estimate formation constants by the various methods described by previous authors. Grain-size data were available only from one aquifer test site, so field coefficients determined at this site were used as a basis for comparison.

Mean grain sizes and standard deviations for each sample interval of test hole 17-35W-29cbc$_1$ were computed from Figure 16 and plotted on the predictive curves developed by Masch and Denny (1966). The permeability coefficients read from the curves were multiplied by the sample interval and these products added to get an estimated transmissibility coefficient. The estimated value was much less than the field coefficient of transmissibility. The mean grain size of each sample was then plotted on a graph relating median grain size to permeability developed by Bedinger (1961). Again the computed transmissibility was lower than the field-determined coefficient.

The effective grain size (90 percent retained size) of each sample

was determined from Figure 16 and plotted on the graph, developed by Rose and Smith (1957), of effective grain size versus permeability. Permeability coefficients were much higher than the values determined by aquifer tests for two of the samples, whereas the effective grain sizes of the other two samples were too low to fit the curve. This evidence suggests that the grain-size analyses do not represent accurately the grain size and degree of sorting of the sediments that determine the permeability of the aquifer.

The samples collected from the test holes in the project area represent a mixture of the material encountered in fifteen feet of bit penetration. Since the exact sample depth cannot be determined, a sample may contain sediment from more than one layer. Although the layers represented in one sample may be relatively well sorted, the sieve analysis could show the sample as a whole to be poorly sorted depending on the difference in grain size between the layers. Parameters which express the degree of sorting of the samples, then, would not reflect the permeability of the layers which make up the aquifer. The mean grain size of the sample, although not indicative of the mean grain size of the layers, could be used as a general expression of the relative volume of the different size fractions present in the sample interval.

Estimations of permeabilities may be made from well logs without grain size analysis data. Fader et al. (1964) and Gutentag and Stullken (1976) estimated transmissibility values from driller's and sample logs by assigning permeability values to the individual layers and multiplying by the thickness of the layer. The sum of these products was then compared to the transmissibility determined from aquifer tests and the permeabilities adjusted accordingly until values were obtained that could be applied

throughout the area of study. Since composite logs of test holes and driller's logs are available for the project area, it should be possible to adapt this method to estimate the permeabilities of the saturated zone.

From the average grain size determined for each layer at test hole 17-36W-29cbc$_1$, the following permeabilities were assigned:

gravel and very coarse sand . . . . . . 2500 gpd/ft^2
coarse to medium sand . . . . 1700 gpd/ft^2
fine to very fine sand. . . . . 1000 gpd/ft^2
silt and clay . . . . 150 gpd/ft^2

These values were determined by taking the permeabilities estimated by Gutentag and Stullken (1976, p. 18) and adjusting to fit the transmissibility obtained from the aquifer test at 17-36W-29cbc. Layer thicknesses used in the estimation were determined from geophysical and descriptive logs of the test hole as shown in Figure 18. The average permeabilities at other test hole sites were estimated by multiplying the layer permeability by the layer thickness determined from composite logs and adding these products to get the transmissibility of the saturated zone (Table 3).

Table 3. Estimated transmissibilities and permeabilities

Location of Composite Log	Coef. of Transmissibility (gpd/ft)	Saturated Thickness (ft)	Average Coef. of Permeability (gpd/ft^2)
17-35W-19bbb	102800	52	1960
17-35W-29cbc	104700	61	1720
17-35W-31cbb	35000	47	745
17-36W-25aaa	60700	48	1260
17-36W-26aaa	58400	45	1300
17-36W-26sbb	36600	35	1050
17-36W-35cdd	65500	55	1190

When this method was used with driller's logs, the average permeabilities obtained were smaller than those estimated from composite logs. Driller's logs are less detailed than the composite logs, and grain size

descriptions are only approximate. Without field-measured permeabilities at driller's log sites, layer permeability values cannot be adjusted for use with driller's log descriptions.

The range of permeabilities computed (745-1960gpd/ft/ft) agrees with permeability coefficients determined by earlier authors in west-central Kansas (Prescott et al., 1954, p. 35; Slagle and Weakly, 1976, p. 11; Gutentag and Stullken, 1976, p. 15). Comparison of the estimated coefficients of permeability to the water-table contour map (Fig. 5) shows that the largest estimated permeability value corresponds to an area where the slope of the water table is least. In general, the estimated permeabilities are larger in the north and east part of the project and smaller in the south part, however, the discontinuity of permeable layers as indicated by the well logs suggests that the permeability of the aquifer may vary greatly within a short distance.

The major obstacle in the indirect determination of permeability coefficients in the project area is the absence of reliable field determined coefficients with which to compare estimated values. Consequently, more accurate estimates will be possible when further aquifer test data are available.

SUMMARY

The water-table contour map indicates that water is flowing from west to east across the study area. Inflow also occurs from the north and south, Ladder Creek acting as a possible source of recharge on the north. The water table has declined an average of about 50 feet in the area since 1948 with the greatest decline in the central and west-central parts. About 50 percent of the 1948 saturated thickness of the aquifer has been

dewatered, leaving 50 to 60 feet of the formation still saturated with water.

Well logs and sample analyses reflect the heterogeneity of the Ogallala Formation in the area. The aquifer is composed of discontinuous clay, sand, and gravel layers. Only the tightly cemented mortar beds near the top of the formation and the basal gravel and coarse sand can be traced throughout the area in geologic cross sections. A relatively thick, impermeable clay layer just above the basal sand is indicated in some of the test hole logs, suggesting that semi-confining conditions prevail in parts of the project area.

Mechanical analyses of drill cuttings demonstrate the vertical variation of the Ogallala aquifer. Sediments from the portion of the aquifer which has been dewatered are finer and less uniform than material from the zone of saturation, so the coefficient of permeability of the saturated sediments is probably greater. The greater permeability of the lower part of the formation has probably reduced the rate of decrease in transmissibility as the aquifer is dewatered.

The hydrologic properties of the formation computed from aquifer test analyses vary greatly within the study area. Differences in transmissibility between the two test sites can be explained by differences in lithology, although no geologic information is available at the first test site to confirm this explanation. A storage coefficient characteristic of an artesian aquifer was determined at the first test site, but geologic information from other areas in the project preclude the possibility of confining conditions existing. Future aquifer tests conducted for longer periods of time should produce storage coefficients characteristic of unconfined or semi-confined conditions.

Coefficients of transmissibility and permeability estimated from test hole logs show the range in water-yielding capacity of the sediments throughout the study area. The largest estimated permeabilities correspond to areas where the hydraulic gradient determined from the water-table contour map is least. Further hydrologic information from the northeastern part of the project could confirm whether the water-yielding capacity of the aquifer is greater in this area.

Although geologic data indicate large reserves of ground water still available, the large decrease in saturated thickness and corresponding loss of yield in existing irrigation wells make further irrigation development of ground-water reserves unadvisable.

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APPENDIX I

Appendix I. LOGS OF TEST HOLES

The following composite logs were constructed from geophysical and sample logs of stratigraphic test holes drilled by the U. S. Geological Survey in the summer and fall of 1977. The logs are listed by increasing section and range number according to the numbering system described in the text. Elevations of test holes were determined to the nearest five feet from the Pence 15 minute quadrangle and the Russell Springs 3 SE 7.5 minute quadrangle.

17-35W-19bbb.--Drilled August 25, 1977. Surface altitude 3,229 feet.

	Thickness	Depth
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Silt, clayey, duskey brown	3	3
Silt, clayey, sandy, gray-borwn	3	6
Clay, silty, sandy, dark yellow-brown	10	16
Silt, sandy, clacareous, very pale-orange	8	24
Clay, silty, very sandy, very pale-orange	7	31
Sand, silty, clayey, calcareous	7	38
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Caliche, lightly cemented sand, very coarse	8	46
Clay, sandy, light-brown	5	51
Sand, lightly lime-cemented, fine to medium	8	59
Clay, sandy, calcareous, very pale-orange	6	65
Sand, fine to very coarse	9	74
Sand, lime-cemented, fine to coarse	3	77
Sand, fine to very coarse, interbedded with silty clay, pale yellow-brown	19	96
Sand, very fine to very coarse, some lightly cemented	11	107
Clay, sandy, very light-brown	5	112
Sand, very fine to very coarse	8	120
Clay, light-brown, interbedded with cemented sand	6	126
Sand, very fine to very coarse, with thin layers of clay and cemented sand	16	142
Clay, silty, sandy, light-brown	4	146
Sand, silty, very fine to very coarse	3	149
Clay, silty, light-brown	1	150
Sand, silty, very fine to very coarse	11	161

17-35W-19bbb.--Continued	Thickness	Depth
Sand, medium to very coarse; and fine gravel- - - - - - - - - - - - - - - - - - - -	16	177
Gravel, fine; and fine to very coarse sand with a few thin clay layers- - - - - -	17	194
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk Formation -- Smokey Hill Chalk Member		
Clay, grayish-orange - - - - - - - - - - - - - -	21	215
Shale, grayish-brown - - - - - - - - - - - - - -	7	222

17-35W-29cbc.--Drilled October 18, 1977. Surface altitude 3,220 feet

QUATERNARY SYSTEM	Thickness	Depth
Pleistocene Series, undifferentiated		
Silt, clayey, grayish-brown- - - - - - - - - -	4	4
Silt, clayey, moderate-brown - - - - - - - - -	2	6
Silt, sandy, light-brown to tan-brown- - - - -	14	20
Silt, clayey, sandy, very light-brown- - - - -	6	26
Silt and very fine sand, lime-cemented, hard -	5	31
Sand, silty, very fine to medium - - - - - - -	10	41
Sand, very fine to very coarse, with some fine gravel- - - - - - - - - - - - - - - - - - - -	4	45
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Sand, very fine, lime-cemented, hard - - - - -	2	47
Sand, very fine to coarse, silty - - - - - - -	3	50
Sand, very fine, lime-cemented, hard - - - - -	7	57
Clay, sandy, light-brown - - - - - - - - - - -	7	64
Chert, white with black veins, very hard - - -	2	66
Sand, clayey - - - - - - - - - - - - - - - - - -	4	70
Sand, very fine to coarse, interbedded with cemented sand - - - - - - - - - - - - - - - -	20	90
Clay, silty, sandy - - - - - - - - - - - - - - -	2	92
Sand, clayey, fine to very coarse- - - - - - -	13	105
Clay, silty, light tan-brown - - - - - - - - -	5	110
Sand, very fine to coarse- - - - - - - - - - -	3	113
Clay, silty- - - - - - - - - - - - - - - - - - -	3	116
Sand, clayey, very fine to coarse- - - - - - -	18	134
Sand, fine to very coarse- - - - - - - - - - -	24	158
Sand, clayey, fine to very coarse- - - - - - -	7	165
Clay, silty- - - - - - - - - - - - - - - - - - -	11	176
Sand, fine to very coarse- - - - - - - - - - -	13	189
Silt, sandy- - - - - - - - - - - - - - - - - - -	2	191
Sand, medium to very coarse, with fine gravel-	19	210
Sand, silty- - - - - - - - - - - - - - - - - - -	6	216

17-35W-29cbc.--Continued

CRETACEOUS SYSTEM	Thickness	Depth
Upper Cretaceous Series		
Niobrara Chalk Formation -- Smoky Hill Chalk Member		
Clay, yellow-orange; and gray shale- - - - - -	9	225

17-35W-31cbb.--Drilled August 23, 1977. Altitude 3,232 feet.

QUATERNARY SYSTEM	Thickness	Depth
Pleistocene Series, undifferentiated		
Silt, clayey, dark-brown - - - - - - - - - - - -	3	3
Silt, light-brown, some sand, coarse - - - - -	12	15
Silt, clayey, light-brown- - - - - - - - - - -	3	18
Silt, clayey, sandy, very light-brown- - - - -	3	21
Clay, silty, very light-brown- - - - - - - - -	3	24
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Mortar bed, hard, light-tan to white, with white clay- - - - - - - - - - - - - - - - - -	8	32
Sand, coarse, lime-cemented, interbedded with light-brown clay - - - - - - - - - - - -	12	44
Sand, coarse to very coarse- - - - - - - - - -	7	51
Sand, fine to very coarse, lime-cemented, hard- -	8	59
Clay, silty, light-brown - - - - - - - - - - -	3	62
Clay, light-brown, with cemented sand, very fine- -	5	67
Clay, light-brown, sandy - - - - - - - - - - -	5.5	72.5
Sand, fine to very coarse, alternating with light-brown clay- - - - - - - - - - - - - -	31.5	104
Sand, fine to very coarse, and fine gravel - -	2.5	106.5
Clay, very sandy, some fine gravel - - - - - -	2	108.5
Sand, fine to very coarse- - - - - - - - - - -	3.5	112
Clay, sandy, light-brown - - - - - - - - - - -	4	116
Mortar bed, lime-cemented sand, fine to very coarse, fine gravel - - - - - - - - - - - -	7	123
Sand, very fine to medium, some fine gravel- -	5	128
Clay, very sandy - - - - - - - - - - - - - - -	6	134
Sand, fine to coarse - - - - - - - - - - - - -	11	145
Silt, sandy, light-brown - - - - - - - - - - -	2	147
Sand, silty, very fine to fine - - - - - - - -	8	155
Clay, silty, dark yellow-orange, interbedded with very fine sand - - - - - - - - - - - -	27	182
Sand, fine to coarse - - - - - - - - - - - - -	4	186
Sand, coarse to very coarse- - - - - - - - - -	5	191
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk Formation -- Smoky Hill Chalk Member		
Clay, pale yellowish-orange, sandy - - - - - -	5	196
Shale, dark grayish-brown, soft- - - - - - - -	14	210

17-36W-25aaa.--Drilled August 24, 1977. Surface altitude 3,230 feet.

	Thickness	Depth
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Silt, clayey, moderate brown	5	5
Silt, clayey, sandy, olive-brown	5	10
Silt, clayey, yellow-brown	3	13
Silt, sandy, very light-gray	10	23
Sand, silty	6	29
Clay, sandy, calcareous, very light gray	4	33
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Mortar bed; cemented sand, medium to very coarse	2	35
Sand, medium to coarse	3	38
Sand, medium to very coarse; and fine gravel	5.5	43.5
Sand, cemented very fine	3.5	47
Sand, very fine to medium	9	56
Sand, fine, clayey	2	58
Mortar bed; lime-cemented sand, fine to coarse	3	61
Clay, sandy, light-brown	3	64
Sand, medium to very coarse, clayey	6	70
Sand, fine to coarse	4	74
Sand, clayey, fine to very coarse	8	82
Sand, very fine to coarse; and fine gravel	6	88
Sand, clayey, very fine to very coarse	4.5	92.5
Sand, lightly cemented, very fine to coarse	6	98.5
Sand, clayey, very fine to medium	3.5	102
Clay, very sandy, light-brown	2.5	104.5
Sand, very fine to coarse, some cemented, alternating with silty clay	30.5	135
Sand, medium to very coarse, and fine gravel	8	143
Clay, sandy, light-brown	7	150
Sand, clayey, very fine to coarse	5	155
Sand, very fine to coarse; and fine gravel	25	180
Sand, very clayey, medium to coarse	5.5	185.5
Sand, medium to very coarse, some fine gravel	4.5	190
Sand, clayey, medium to coarse	3	193
Gravel, fine; and sand, coarse to very coarse	5	198
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk Formation -- Smoky Hill Member		
Clay, yellowish-orange	15	213
Shale, dark gray-brown, soft	13	226

17-36W-26aaa.--Drilled August 25, 1977. Surface altitude 3,243 feet.

	Thickness	Depth
QUATERNAY SYSTEM		
Pleistocene Series, undifferentiated		
Silt, clayey, light-brown- - - - - - - - - - - -	8	8
Silt, sandy, clayey, gray-brown- - - - - - - - -	8	16
Sand, silty, fine to medium- - - - - - - - - - -	6	22
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Caliche, sandy, clayey, pale-brown to white- -	6	28
Clay, sandy, white, interbedded with very fine to fine sand - - - - - - - - - - - - - -	8	36
Sand, fine to very coarse- - - - - - - - - - - -	7	43
Sand, medium to very coarse, lightly cemented-	2	45
Sand, silty, fine to very coarse - - - - - - -	2.5	47.5
Sand, medium to very coarse- - - - - - - - - - -	3.5	51
Clay, sandy, moderate-brown, interbedded with fine to very coarse sand- - - - - - - - - -	14	65
Sand, silty, fine to coarse- - - - - - - - - - -	5	70
Sand, coarse to very coarse, and gravel, cemented- - - - - - - - - - - - - - - - - - -	6	76
Sand, very fine to very coarse, interbedded with clay, sandy, pale yellow-brown - - - -	35	111
Clay, sandy, moderate brown- - - - - - - - - - -	4	115
Sand, silty, very fine to very coarse- - - - -	9	124
Clay, sandy, moderate brown- - - - - - - - - - -	5	129
Sand, very fine to very coarse, interbedded with clay, pale yellow-brown- - - - - - - -	13	142
Sand, very fine to very coarse, lightly cemented- - - - - - - - - - - - - - - - - - -	6	148
Clay, silty, yellow-brown- - - - - - - - - - - -	3	151
Sand, silty, very fine to very coarse, some lightly cemented- - - - - - - - - - - - - - -	8	159
Sand, very fine to very coarse, interbedded with clay, silty, brown - - - - - - - - - - -	8	167
Sand, lime-cemented- - - - - - - - - - - - - - -	2	169
Sand, very fine to very coarse; and clay, silty, dark yellow-orange - - - - - - - - - -	8	177
Clay, silty, dark yellow-orange- - - - - - - - -	7	184
Sand, medium to very coarse; and gravel, fine-	13	197
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk Formation -- Smoky Hill Member		
Clay, pale yellow-orange - - - - - - - - - - - -	14	211
Shale, firm, duskey-brown- - - - - - - - - - - -	24	235

17-36W-26cbb.--Drilled October 18, 1977. Surface altitude 3,254 feet.

	Thickness	Depth
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Silt, clayey, light-brown- - - - - - - - - - - -	14	14
Silt, sandy- - - - - - - - - - - - - - - - - - -	6	20
Sand, silty, very fine to medium lime-cemented -	4	24
Sand, silty, clayey, very fine to coarse - - - -	19	43
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Mortar bed; lime-cemented silt and sand- - - - -	3.5	46.5
Sand, silty, lightly cemented- - - - - - - - - -	4	50.5
Clay, silty- - - - - - - - - - - - - - - - - - -	8	58.5
Sand, silty, very fine to coarse, alternating with layers of silty clay - - - - - - - - - -	22	80.5
Sand, silty, very fine to very coarse, some lightly cemented- - - - - - - - - - - - - - - -	39.5	120
Clay, silty, sandy - - - - - - - - - - - - - - -	13	133
Sand, silty, very fine to coarse - - - - - - - -	5	138
Clay, silty- - - - - - - - - - - - - - - - - - -	2	140
Sand, very fine to very coarse - - - - - - - - -	15	155
Sand, silty, very fine to coarse - - - - - - - -	11	166
Sand, very fine to very coarse - - - - - - - - -	10	176
Silt, sandy, clayey- - - - - - - - - - - - - - -	7	183
Sand, fine to very coarse; and fine gravel - - -	7	190
CRETACEOUS SYSTEM		
Uppler Cretaceous Series		
Niobrara Chalk Formation -- Smoky Hill Chalk Member		
Clay, pale yellow-orange - - - - - - - - - - - -	6	196

17-36W-35cdd.--Drilled August 24, 1977. Surface altitude 3,248 feet.

	Thickness	Depth
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Clay, silty, dark-brown- - - - - - - - - - - - -	3	3
Silt, clayey, grayish-orange - - - - - - - - - -	7	10
Silt, sandy, grayish-orange- - - - - - - - - - -	4	14
Clay, silty, very light-brown- - - - - - - - - -	3	17
Silt, clayey, light-brown- - - - - - - - - - - -	2.5	19.5
Silt, sandy, clayey, white to very light brown -	4.5	24
Clay, silty, calcareous, white to light brown- -	8	32
Sand, very fine, cemented; and caliche, white- -	3	35
Sand, coarse to very coarse, subrounded- - - - -	9	44

<u>17-36W-35cdd</u>.--Continued

	Thickness	Depth
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Mortar bed, hard; cemented sand, fine to very coarse; and fine to medium gravel - - - - -	9	53
Clay, light-brown- - - - - - - - - - - - - - -	2	55
Sand, medium to coarse; lime-cemented silt - -	8	63
Clay, silty, sandy, light-brown- - - - - - - -	7	70
Sand, medium to very coarse; gravel, fine; and lime-cemented silt- - - - - - - - - - - - -	6	76
Clay, sandy, light-brown - - - - - - - - - - -	2	78
Sand, very fine to coarse; and fine gravel - -	9	87
Mortar bed, hard; lime-cemented silt and sand-	2	89
Sand, very fine to medium, slightly clayey, dark reddish-brown- - - - - - - - - - - - -	10	99
Sand, clayey, dark reddish-brown - - - - - - -	17	116
Clay, silty, sandy, yellowish-brown- - - - - -	9	125
Sand, clayey, very fine to coarse- - - - - - -	10	135
Sand, fine to coarse; some fine gravel - - - -	6	141
Sand, coarse to very coarse; and fine gravel -	5	146
Sand, clayey, medium to very coarse- - - - - -	6	152
Sand, medium to very coarse; and fine gravel -	4	156
Sand, fine to very coarse; interbedded with clay, yellowish-brown - - - - - - - - - - -	20	176
Sand, fine to coarse - - - - - - - - - - - - -	10	186
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk Formation -- Smoky Hill Chalk Member		
Clay, sandy, yellowish-orange- - - - - - - - -	8	194
Shale, dark grayish-brown- - - - - - - - - - -	16	210

APPENDIX II

Appendix II. SAMPLE GRAIN-SIZE DATA

Grain-size data for test hole 17-35W-19bbb showing fraction weight and cumulative percent retained.

Mesh number	Phi interval	Sample Depth 90-105 Wt. (gm.)	Cum. %	105-120 Wt. (gm.)	Cum. %	120-135 Wt. (gm.)	Cum. %	135-150 Wt. (gm.)	Cum. %	150-165 Wt. (gm.)	Cum. %	165-180 Wt. (gm.)	Cum. %	180-195 Wt. (gm.)	Cum. %
5/16	-3											0.9	1.4		
5	-3- -2											9.4	16.3	5.2	7.2
10	-2- -1	1.6	3.7	1.7	3.8			0.3	0.5	1.0	1.5	16.6	42.7	7.1	16.9
18	-1 - 0	5.3	16.0	3.9	12.4	2.2	5.8	3.0	5.9	5.5	9.6	18.0	71.3	21.0	45.8
35	0 - 1	11.3	42.1	8.4	30.9	7.4	25.3	16.0	34.4	23.4	44.4	10.7	88.2	22.6	76.9
60	1 - 2	14.6	75.9	16.4	67.1	13.6	61.2	21.9	73.4	25.5	82.2	5.8	97.5	12.9	94.6
120	2 - 3	6.1	90.0	8.3	85.4	9.2	85.5	8.7	88.9	7.2	92.9	0.7	98.6	2.1	97.5
230.	3 - 4	2.3	95.4	3.5	93.2	3.0	93.4	3.4	95.0	2.1	96.0	0.3	99.0	0.7	98.5
pan	4	2.0	100.	3.1	100.	2.5	100.	2.8	100.	2.7	100.	0.6	100.	1.1	100.
Total weight		43.2		45.3		37.9		56.1		67.4		63.0		72.7	

Grain-size data for test hole 17-35W-29cbc$_1$ showing fraction weight and cumulative percent retained.

Mesh number	Phi interval	Sample Depth 90-105 Wt. (gm.)	Cum. %	105-120 Wt. (gm.)	Cum. %	120-135 Wt. (gm.)	Cum. %	135-150 Wt. (gm.)	Cum. %	150-165 Wt. (gm.)	Cum. %	165-180 Wt. (gm.)	Cum. %	180-195 Wt. (gm.)	Cum. %	195-210 Wt. (gm.)	Cum. %
5	-3- -2	0.9	2.6			0.2	0.6	3.2	6.0	1.5	2.5			0.1	0.2		
10	-2- -1	1.1	5.8	0.5	2.0	0.4	1.6	19.0	41.5	1.8	5.5	0.6	1.3	1.5	2.4	4.5	5.1
18	-1 - 0	3.9	17.1	0.7	4.8	2.8	9.4	17.2	73.6	3.8	11.8	1.1	3.7	13.3	22.4	25.9	34.3
35	0 - 1	7.3	38.3	4.1	21.2	6.5	27.3	3.9	80.9	18.4	42.2	4.8	14.3	26.9	62.9	40.9	80.5
60	1 - 2	9.5	65.8	8.4	54.8	13.5	64.5	2.5	85.6	17.9	71.8	10.4	37.1	15.7	86.5	12.9	95.0
120	2 - 3	6.2	83.8	6.1	79.2	7.3	84.6	5.0	95.0	10.1	88.6	5.2	48.5	4.0	92.5	2.1	97.4
230	3 - 4									1.7	91.4	5.4	60.3	2.0	95.5	1.0	98.5
325	4 -4.5											5.0	71.3				
pan	4.5	5.6	100.	5.2	100.	5.6	100.	2.7	100.	5.2	100.	13.1	100.	3.0	100.	1.3	100.
Total weight		34.5		25.0		36.3		53.5		60.4		45.6		66.5		88.6	

Grain-size data for test hole 17-35W-31cbb showing fraction weight and cumulative percent retained.

Mesh number	Phi interval	90-105 Wt. (gm.)	90-105 Cum. %	105-120 Wt. (gm.)	105-120 Cum. %	120-135 Wt. (gm.)	120-135 Cum. %	135-150 Wt. (gm.)	135-150 Cum. %	150-165 Wt. (gm.)	150-165 Cum. %	165-180 Wt. (gm.)	165-180 Cum. %	180-195 Wt. (gm.)	180-195 Cum. %
		Sample Depth													
5	-3- -2	11.0	21.8	7.3	10.9	2.2	3.2	0.5	0.6	0.2	0.3	0.3	3.6		
10	-2- -1	7.4	36.5	13.6	31.3	1.6	5.6	2.0	3.1	0.4	0.8	0.1	4.8	3.4	3.7
18	-1- 0	5.3	47.0	15.1	54.0	5.9	14.2	8.6	13.6	1.7	3.0	0.3	8.3	16.0	32.7
35	0 - 1	7.8	62.5	12.2	72.3	20.1	43.6	24.1	43.2	18.0	26.3	1.4	25.0	23.2	71.8
60	1 - 2	6.2	74.8	7.3	83.2	17.9	69.7	25.9	75.0	35.9	72.8	1.4	41.7	9.0	87.0
120	2 - 3	4.8	84.3	4.5	90.0	9.0	82.9	11.0	88.5	10.9	86.9	0.6	48.8	2.6	91.4
230	3 - 4	3.7	91.7	3.3	94.9	6.3	92.1	5.2	94.8	5.5	94.0	1.8	70.2	2.1	94.9
pan	4	4.2	100.	3.4	100.	5.4	100.	4.2	100.	4.6	100.	2.5	100.	3.0	100.
Total weight		50.4		66.7		68.4		81.5		77.2		8.4		59.3	

Grain-size data for test hole 17-36W-25aaa showing fraction weight and cumulative percent retained.

Mesh number	Phi interval	90-105 Wt. (gm.)	90-105 Cum. %	105-120- Wt. (gm.)	105-120- Cum. %	120-135 Wt. (gm.)	120-135 Cum. %	135-150 Wt. (gm.)	135-150 Cum. %	150-165 Wt. (gm.)	150-165 Cum. %	165-180 Wt. (gm.)	165-180 Cum. %	180-195 Wt. (gm.)	180-195 Cum. %
		Sample Depth													
1/4	-2.6													1.5	2.0
4	-2.6- -2.2	0.1	0.1							0.6	1.0			2.2	5.0
10	-2.2- -1	1.5	3.2	0.1	0.2	0.3	0.9	9.7	14.3	7.1	12.5	5.5	6.6	24.4	38.0
18	-1 - 0	3.2	9.6	1.4	2.7	1.1	4.1	17.8	40.7	8.4	26.0	18.2	28.6	19.2	63.9
35	0 - 1	9.0	27.5	10.6	21.4	3.4	14.0	19.6	69.7	22.9	63.1	18.9	51.4	13.0	81.5
120	1 - 3	22.8	72.9	33.1	79.9	24.7	86.0	16.1	93.5	17.5	91.4	23.8	80.1	6.7	90.5
230	3 - 4	5.3	86.1	5.8	90.1	2.5	93.3	2.2	96.7	2.3	95.2	4.2	85.2	4.2	96.4
pan	4	5.6	100.	5.6	100.	2.3	100.	2.2	100.	3.0	100.	12.2	100.	2.5	100.
Total weight		50.2		56.6		34.3		67.6		61.8		82.8		73.7	

Grain-size data for test hole 17-36W-26aaa showing fraction weight and cumulative percent retained.

Mesh number	Phi interval	90-105 Wt. (gm.)	90-105 Cum. %	105-120 Wt. (gm.)	105-120 Cum. %	120-135 Wt. (gm.)	120-135 Cum. %	135-150 Wt. (gm.)	135-150 Cum. %	150-165 Wt. (gm.)	150-165 Cum. %	165-180 Wt. (gm.)	165-180 Cum. %	180-195 Wt. (gm.)	180-195 Cum. %
		Sample Depth													
5	-3- -2			0.1	0.1			0.5	0.6			0.4	0.6	4.0	6.6
10	-2- -1	0.7	2.1	2.8	3.7	10.2	11.6	3.6	5.2	0.9	1.2	1.6	3.1	6.7	17.5
18	-1 - 0	4.5	15.9	9.7	15.9	4.8	17.1	6.5	14.6	3.0	5.4	8.3	16.0	15.3	42.6
35	0 - 1	4.9	30.8	22.1	43.7	14.8	33.9	23.2	43.4	19.6	32.5	20.9	48.4	16.6	69.8
60	1 - 2	7.2	52.9	21.8	71.1	26.3	63.9	20.1	69.2	21.6	62.4	16.5	74.0	9.1	84.8
120	2 - 3	4.6	67.0	11.1	85.1	16.7	82.9	13.2	86.1	14.6	82.6	8.0	86.4	4.6	92.3
230	3 - 4	5.0	82.3	6.8	93.7	9.2	93.4	6.8	94.9	6.8	92.0	4.6	93.5	2.4	96.2
pan	4	5.8	100.	5.0	100.	5.8	100.	4.0	100.	5.8	100.	4.2	100.	2.3	100.
Total weight		32.7		79.4		87.8		77.9		72.3		64.5		61.0	

Grain-size data for test hole 17-36W-26cbb[1] showing fraction weight and cumulative percent retained. Only samples from depths greater than 150 feet were analyzed.

Mesh number	Phi interval	150-165 Wt. (gm.)	150-165 Cum. %	165-180 Wt. (gm.)	165-180 Cum. %	180-195 Wt. (gm.)	180-195 Cum. %
		Sample Depth					
5/16	-3					2.2	3.2
5	-3- -2			0.2	0.3	5.0	10.4
10	-2- -1	0.3	0.3	3.4	4.9	20.0	39.5
18	-1 - 0	3.9	4.7	15.3	25.7	19.4	67.6
35	0 - 1	29.5	38.0	20.7	53.8	12.4	85.6
60	1 - 2	35.0	77.4	16.6	76.4	4.7	92.5
120	2 - 3	11.7	90.5	7.4	86.4	1.9	95.2
230	3 - 4	5.6	96.8	4.9	93.1	1.3	97.1
pan	4	2.8	100.	5.1	100.	2.0	100.
		88.8		73.6		68.9	

Grain-size data for test hole 17-36W-35cdd showing fraction weight and cumulative percent retained.

Mesh number	Phi interval	Sample Depth 90-105		105-120		120-135		135-150		150-165		165-180	
		Wt. (gm.)	Cum. %	Wt. (gm.)	Cum. %	Wt. (gm.)	Cum. %	Wt, (gm.)	Cum. %	Wt. (gm.)	Cum. %	Wt. (gm.)	Cum. %
5	-4- -3	0.4	1.2			0.2	0.9	10.0	12.1	3.4	6.8	0.1	0.2
10	-3- -2	0.5	2.6	0.5	1.2	0.9	4.7	20.2	36.6	5.2	17.1	0.9	1.9
18	-2- -1	1.0	5.5	1.1	3.8	3.7	20.7	14.0	53.5	4.9	26.8	7.3	15.7
35	-1 - 0	5.5	21.4	2.6	10.1	1.4	26.7	13.3	69.6	10.6	47.9	15.3	44.8
60	0 - 1							11.3	83.3	9.9	67.6	17.4	77.8
120	1 - 2	14.2	62.2	21.4	61.4	12.2	79.3	6.7	91.4	6.7	80.9	6.5	90.1
230	2 - 3	6.0	80.0	7.3	78.9	2.2	88.8	3.6	95.8	3.9	88.7	2.6	95.1
pan	3	6.9	100.	8.8	100.	2.6	100.	3.5	100.	5.7	100.	2.6	100.
Total weight		34.5		41.7		23.2		82.6		50.3		52.7	

APPENDIX III

Appendix III. AQUIFER TEST DATA

Data on aquifer test of well 17-36W-23bcc$_2$ conducted October 13, 1977.

Time of pumping (min.)	Observed drawdown (feet)	Adjusted drawdown[a] (feet)	Yield (gpm)
0	0.00	0.00	
0.25	0.05	0.05	
0.50	0.49	0.49	
0.75	0.91	0.90	
1.00	1.30	1.28	
1.25	1.78	1.76	
1.50	2.22	2.16	
1.75	2.73	2.64	
2.00	3.13	3.01	
2.50	3.87	3.69	
3.00	4.50	4.26	
3.50	4.99	4.69	
4.00	5.41	5.06	
4.50	5.85	5.44	
5.00	6.16	5.71	
5.50	6.58	6.06	
6.00	6.81	6.26	
6.50	6.98	6.40	
7.00	7.17	6.56	
7.50	7.36	6.72	
8.00	7.52	6.85	
8.30	7.71	7.00	
9.00	7.80	7.08	
9.30	7.92	7.17	
10.00	8.00	7.24	
10.50	8.09	7.31	
11.00	8.27	7.46	
12.00	8.34	7.51	
13.00	8.54	7.67	
14.00	8.58	7.70	
15.00	8.70	7.80	
16.00	8.85	7.92	
17.00	8.88	7.94	
18.00	8.91	7.96	
19.00	8.93	7.98	
20.00	8.96	8.00	
21.00	9.02	8.05	
22.00	9.09	8.11	348.9
23.00	9.13	8.14	
24.00	9.13	8.14	
25.00	9.18	8.18	
26.00	9.19	8.18	
27.00	9.20	8.19	
28.00	9.21	8.20	
29.00	9.22	8.21	
30.00	9.24	8.22	348.9
35.00	9.28	8.25	
40.00	9.34	8.30	
45.00	9.37	8.32	
50.00	9.40	8.35	
55.00	9.42	8.36	
60.00	9.45	8.39	348.9
65.00	9.48	8.41	
70.00	9.50	8.43	
75.00	9.51	8.44	
80.00	9.52	8.44	
85.00	9.55	8.46	
90.00	9.57	8.48	
95.00	9.57	8.48	
100.00	9.58	8.49	
130.00	9.65	8.54	
160.00	9.71	8.59	
190.00	9.75	8.62	
220.00	9.76	8.63	320.6
250.00	9.78	8.64	
280.00	9.78	8.64	
310.00	9.81	8.66	
340.00	9.82	8.67	318.8
370.00	9.84	8.69	
400.00	9.86	8.70	
460.00	9.93	8.76	
520.00	9.94	8.76	
580.00	9.59	8.50	325.7
610.00	9.62	8.52	
640.00	9.68	8.56	
670.00	9.80	8.66	
700.00	9.80	8.66	
820.00	9.83	8.68	320.6
940.00	9.85	8.69	
1060.00	9.90	8.73	
1180.00	9.91	8.74	310.2
1300.00	9.93	8.76	315.2
1420.00	9.99	8.80	
1526.00	10.03	8.83	
1572.00	10.10	8.89	

[a]Observed drawdown corrected for dewatering of aquifer above cone of depression.

Data on aquifer test of well 17-35W-29cbc conducted October 28, 1977. Water level recovery was measured in two U. S. G. S. observation wells located 100 and 200 feet from the pumping well. Time since pumping began = 2640 min. Discharge during pumping = 675 gpm. Assumed steady-state water level = 160 feet.

Observation well #1, 100 feet from pumping well.				Observation well #2, 200 feet from pumping well.			
Time since pumping stopped-t' (min.)	t/t'	Recovery (feet)	Residual drawdown (feet)	Time since pumping stopped-t' (min.)	t/t'	Recovery (feet)	Residual drawdown (feet)
0		0.00	20.90	0		0.00	19.50
0.50	5281	0.50	20.40	0.50	5281	5.07	14.43
1.00	2641	1.40	19.50	1.00	2641	5.61	13.89
1.50	1761	2.09	18.81	1.50	1761	6.11	13.39
2.00	1321	2.76	17.14	2.00	1321	6.51	12.99
3.00	881	4.20	16.70	3.00	881	7.25	12.25
4.00	661	5.06	15.85	4.00	661	7.75	11.75
5.00	529	6.12	14.78	5.00	529	8.29	11.21
6.00	441	6.99	13.91	6.00	441	8.78	10.72
7.00	378	7.70	13.20	7.00	378	9.24	10.26
8.00	331	8.47	12.43	8.00	331	9.72	9.78
9.00	294	9.15	11.75	9.00	294	10.15	9.35
10.00	265	9.67	11.23	10.00	265	10.40	9.10
11.00	241	10.16	10.74	11.00	241	10.70	8.80
12.00	221	10.68	10.22	12.00	221	11.03	8.47
13.00	204	11.10	9.80	13.00	204	11.34	8.16
14.00	189	11.39	9.31	14.00	189	11.62	7.88
15.00	177	11.67	9.23	15.00	177	11.84	7.66
20.00	133	13.04	7.86	20.00	133	12.94	6.56
25.00	106.6	13.99	6.91	25.00	106.6	13.71	5.79
30.00	89.0	14.72	6.18	30.00	89.0	14.37	5.13
45.00	59.7	16.07	4.83	45.00	59.7	15.64	3.86
60.00	45.0	16.84	4.06	60.00	45.0	16.40	3.10
90.00	30.3	17.68	3.22	90.00	30.3	17.20	2.30
120.00	23.0	18.09	2.81	120.00	23.0	17.55	1.95
150.00	18.6	18.34	2.56	150.00	18.6	17.84	1.66
180.00	15.7	18.59	2.31	210.00	13.6	18.11	1.39
210.00	13.6	18.64	2.26	240.00	12.0	18.20	1.30
240.00	12.0	18.73	2.17	270.00	10.8	18.29	1.21
270.00	10.8	18.82	2.08	300.00	9.8	18.34	1.16
300.00	9.8	18.88	2.02				

APPENDIX IV

Appendix IV. RECORDS OF IRRIGATION WELLS

Well location[a]	Surface[b] Altitude	Discharge[c] (gpm)	Depth to[d] water (ft.)	Elevation of[e] water table
17-35W-19bbc	3231	475	145	3086
17-35W-19bcc	3232	345	148	3084
17-35W-19ccc	3232	284	152	3080
17-35W-20acd	3210	872	*	3072
17-35W-20ccc	3219	528	152	3067
17-35W-20dcb	3213	778	142	3071
17-35W-29bdc	3221	353	152	3069
17-35W-29cbc	3221	849	151	3070
17-35W-30abb	3226	610	*	3077
17-35W-30bbc	3233	619	154	3079
17-35W-30cbb	3234	625	154	3080
17-35W-30dcb	3228	907	150	3078
17-35W-31abb	3228	273	149	3079
17-35W-31bbb	3234	142	147	3087
17-35W-31ccb$_1$	3234	250	139	3095
17-35W-31ccb$_2$	3234	159	140	3094
17-35W-31dca	3221	256	*	3086
17-35W-32acc	3212	201	143	3069
17-35W-32cbb	3220	340	143	3077
17-36W-23baa	3251	296	149	3102
17-36W-23bcc$_1$	3258	241	152	3106
17-36W-23bcc$_2$	3258	185	152	3106
17-36W-23cdb	3252	592	159	3093
17-36W-24bcb	3245	514	157	3088
17-36W-24cbc	3245	814	158	3087
17-36W-25acc	3238	514	154	3084
17-36W-25bbc	3244	550	156	3088
17-36W-25ccd	3242	750	158	3084
17-36W-25dcc	3240	275	155	3085
17-36W-26acb	3248	217	155	3093
17-36W-26cbb	3254	610	*	3107
17-36W-26dbb	3251	300	155	3096
17-36W-35abb	3251	595	*	3103
17-36W-35bbc	3257	601	*	3114
17-36W-35ccc	3253	320	131	3122
17-36W-36bbb	3246	814	153	3093
17-36W-36cbb	3242	-	137	3105
17-36W-36dba	3231	420	142	3089

[a]Well location: see text for well numbering system

[b]Surface altitude: determined to nearest five feet from base map

[c]Discharge: measured during the summer of 1977 by U. S. G. S. personnel

[d]Depth to water: measured during winter of 1977 except where indicated by *

[e]Elevation of water table: estimated from water table contour map where no water level data was available

THE HYDROGEOLOGY OF AN AREA NEAR
MARIENTHAL, WICHITA COUNTY, KANSAS

by

MARTIN S. JOHNSON

B. S., Kansas State University, 1974

AN ABSTRACT OF A MASTER"S THESIS

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The hydrogeology of an irrigated area in Wichita County was studied to determine the geologic controls on the availability of ground water. Ground water in the area is derived from the Ogallala Formation of Tertiary age, composed of interbedded sand, gravel, silt, and clay. The upper part of the Ogallala is often cemented by calcium carbonate, forming 'mortar beds'.

The configuration of the water table was determined from water level data supplied by the U. S. Geological Survey. Movement of ground water is to the east, with inflow occurring from the north and southwest. Since 1950, the water table has declined from 40 to 60 feet, causing a 50 percent depletion in saturated thickness through most of the project area.

Geophysical and sample logs of test holes were used to determine the geology of the aquifer and depth to bedrock. Geologic cross sections constructed from the logs show the discontinuity of the clay, sand, and gravel beds. Clay beds overlying permeable sand and gravel layers may cause semi-confining conditions in some areas.

Samples of drill cuttings from test holes were collected and sieve analyses conducted to determine the grain-size distribution of the sediments. The analyses showed a normal 'S-shaped' distribution, with sediments from the saturated zone somewhat coarser and better sorted than material from the dewatered zone.

Aquifer tests were conducted to determine the hydrologic properties of the aquifer. Coefficients of transmissibility ranged from 104,800 gpd/ft at one test site to 7,700 gpd/ft at the other. Representative storage coefficients could not be determined because of the short duration of the tests and types of tests conducted. Storage coefficients reported in other studies in the area are about .15 for unconfined and .0001 for confined sections of the Ogallala aquifer.

Formation constants of the aquifer were estimated at other test hole locations from well logs by assigning a coefficient of permeability value to each layer and multiplying by the thickness of the layer. The estimated permeability values were adjusted until the transmissibilities thus determined agreed with aquifer test results. Average permeability coefficients ranged from 1,960 gpd/ft^2 to 745 gpd/ft^2 for the seven test hole locations. More accurate estimates will be possible when further aquifer test data are available.